

On the Effect of High Temperatures on Radium Emanation.

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1. *Introduction.*

It has been shown by Curie and Danne* that the rate of decay of radium C can be altered by subjecting it to temperatures above 630° C. The rate of decay increases with rise of temperature, reaching a maximum at about 1100° C., after which it again decreases up to 1300° C. The following are some of the values taken from their paper :—

Temperature centigrade.	c' .	θ .
630°	3.94×10^{-4}	29.3
830	4.70×10^{-4}	24.6
1000	5.50×10^{-4}	21.0
1100	5.70×10^{-4}	20.3
1250	4.80×10^{-4}	24.1
1300	4.50×10^{-4}	25.4

Here c' is the radio-active constant, and θ is the time in minutes taken by the activity of radium C to fall to half its value.†

H. L. Bronson‡ has more recently made some experiments on the same subject, and is led to the opposite conclusion. He states that the heating of the active deposit from radium emanation to temperatures between 700° and 1100° C. is without effect, and to explain both his results and those of Curie and Danne, he suggests that radium C has a shorter instead of a longer period than radium B, and that the latter is the more volatile of the two; part of the radium B is, however, in general supposed to have remained on his wires after heating.

In view of the conflicting evidence on the subject, it seemed desirable that further experiments on this important question should be undertaken. The following is an account of an investigation on the influence of temperature on the activity of radium emanation when in radio-active equilibrium with

* 'Comptes Rendus,' vol. 138, pp. 748–751, March, 1904.

† The nomenclature suggested by Rutherford is here adopted, in which radium C is the third product after the emanation.

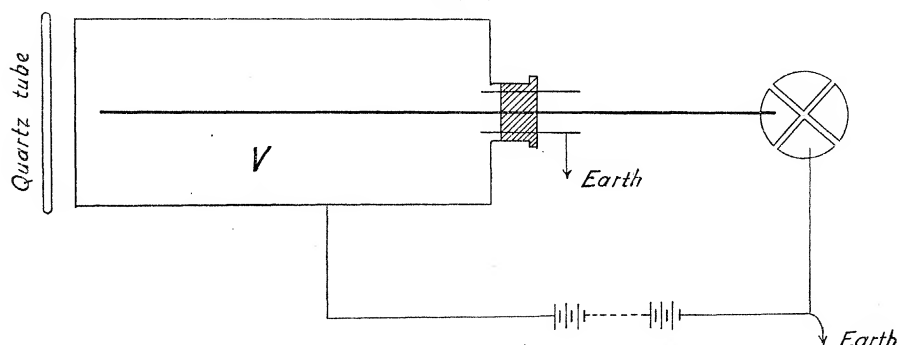
‡ 'Amer. Jour. Sci.,' pp. 60–64, July, 1905, and 'Phil. Mag.,' s. 6, vol. 11, No. 61, January, 1906, p. 143.

radium A, B, and C, and when sealed up in a quartz tube so that there can have been no possibility of the escape of any volatile product. The results show clearly that the activity as measured by the β and γ rays can be changed by high temperatures, the observed effects being *consistent* with the explanation offered by Curie and Danne, that the rate of decay of radium C is increased by high temperatures. The experiments do not, however, *prove* that it is this particular product which is affected, as the results could be equally well explained if one or more of the other radio-active bodies present underwent some alteration. Further experiments will be necessary before this question can be definitely settled, but there can be no doubt that the rate of decay of one of the products is affected by temperature.

2. *Experimental Method.*

The emanation from about 5 milligrammes of radium bromide was collected in a small quartz tube 12 cm. long and 0.5 cm. diameter, closed at one end. The open end was connected to the bulb containing the radium, and the whole apparatus was evacuated, to allow the emanation to diffuse rapidly. The emanation was condensed in the tube by immersing it in liquid air, and sufficient air was admitted to cause the pressure inside the quartz-tube to be about atmospheric when raised to the highest temperatures subsequently to be used. The quartz-tube was then sealed off in an oxyhydrogen blow-pipe at a constriction near its upper end, and removed from the liquid air bath. Its radio-activity was tested by measuring the ionisation produced in a cylindrical metal vessel V (fig. 1) when the quartz-tube was placed on a

FIG. 1.



small wooden stand in the position shown in the figure. The sides of the quartz-tube and the bottom of the vessel V were together thick enough to absorb all the α rays coming from the emanation, but thin enough to let through a considerable portion of the β -rays and most of the γ -rays.

Observations of the ionisation in V therefore afforded a measure of the quantity of radium C present in the quartz-tube, since this is the only radio-active product which emits these rays in sufficient quantity to be of consequence. A saturation current was obtained from 200 small storage cells, and the measurements were made by means of a Dolezalek electrometer.

It was found that the quartz-tube could be removed from its stand and replaced so nearly in the same position that the ionisation in V did not change by an appreciable amount.

After leaving sufficient time for radio-active equilibrium to be established, the activity was measured. The quartz-tube was then placed in an electric furnace and heated to a high temperature for a definite time, the activity being again tested as soon as possible after the removal of the quartz-tube from the furnace.

3. *First Series of Experiments.*

In these experiments a carbon-tube furnace of the kind described by Hutton and Patterson* was used. No accurate measurements of temperature were made in this series of experiments, but the maximum temperature attained was estimated by placing wires of different metals in the furnace on either side of the quartz-tube, and noting which were fused.

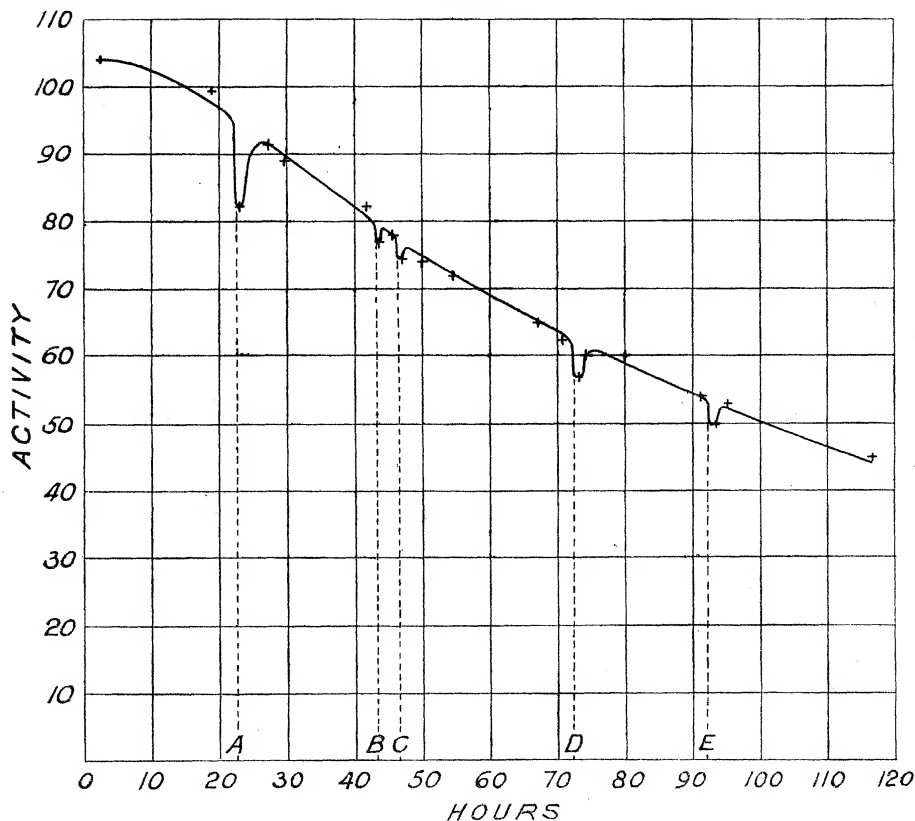
Details of the experiments are given in Table I. The results are also shown graphically in fig. 2, in which the ordinates represent, in arbitrary units, the radio-activity of the emanation, and the abscissæ give time in hours. The zero of time is taken at the moment of sealing of the quartz-tube. The points on the curve represent the means of several observations taken within a few minutes of each other, and the points A, B, C, D, E the times at which the quartz-tube was heated.

Table I.

Experiment.	Time of heating, in minutes.	Temperature between melting points of	Activity.		
			Before heating.	After heating.	Percentage fall.
A	15	Nickel and platinum ...	97	82	15·5
B	15	" " " " ...	82	77	6·1
C	15	Copper and nickel	78	75	3·85
D	31	" " " " ...	62·5	57	8·8
E	24	Slightly above that of nickel	54	50	7·4

* 'Trans. Faraday Soc.,' 1905, vol. 1, pp. 187-196.

FIG. 2.



Leaving out of account the initial stage immediately after filling the tube, the activity of the emanation decreased according to an exponential law, falling to half in 3.7 days. It will, however, be noticed that the activity always fell temporarily after heating the emanation, the activity *recovering to its normal value* in about one hour. The latter point is of importance, as the observed decrease of activity might otherwise be supposed due to the porosity of the quartz when hot to the emanation; but this would leave unexplained the subsequent recovery of the activity to its normal value.

4. *Second Series of Experiments.*

As a result of the frequent heating in a carbon furnace, the quartz-tube used in the previous experiments crystallised and fell to pieces. A new and similar tube was therefore made, with which the following series of experiments was performed. The method was the same as in the first series, except that a small porcelain-tube furnace, heated by the passage of an

electric current through a nickel wire wound on it, was substituted for the carbon-tube furnace. The furnace was similar to those used by Dr. Harker at the National Physical Laboratory. Besides the fact that under these conditions the quartz-tube showed less tendency to crystallise, the advantage of the change consisted in the fact that the quartz-tube could be introduced into the furnace when a steady temperature had been reached, and could be quickly withdrawn while hot, and its activity measured within a few minutes after removal. Furthermore, the furnace temperatures were measured by a platinum-platinum-rhodium thermo-couple standardised at the Reichsanstalt. The temperature of the furnace was very uniform, and remained constant to about 20° C. during an experiment.

The observations are given in Table II., and shown graphically in fig. 3. The general character of the results is similar to that obtained in the first series.

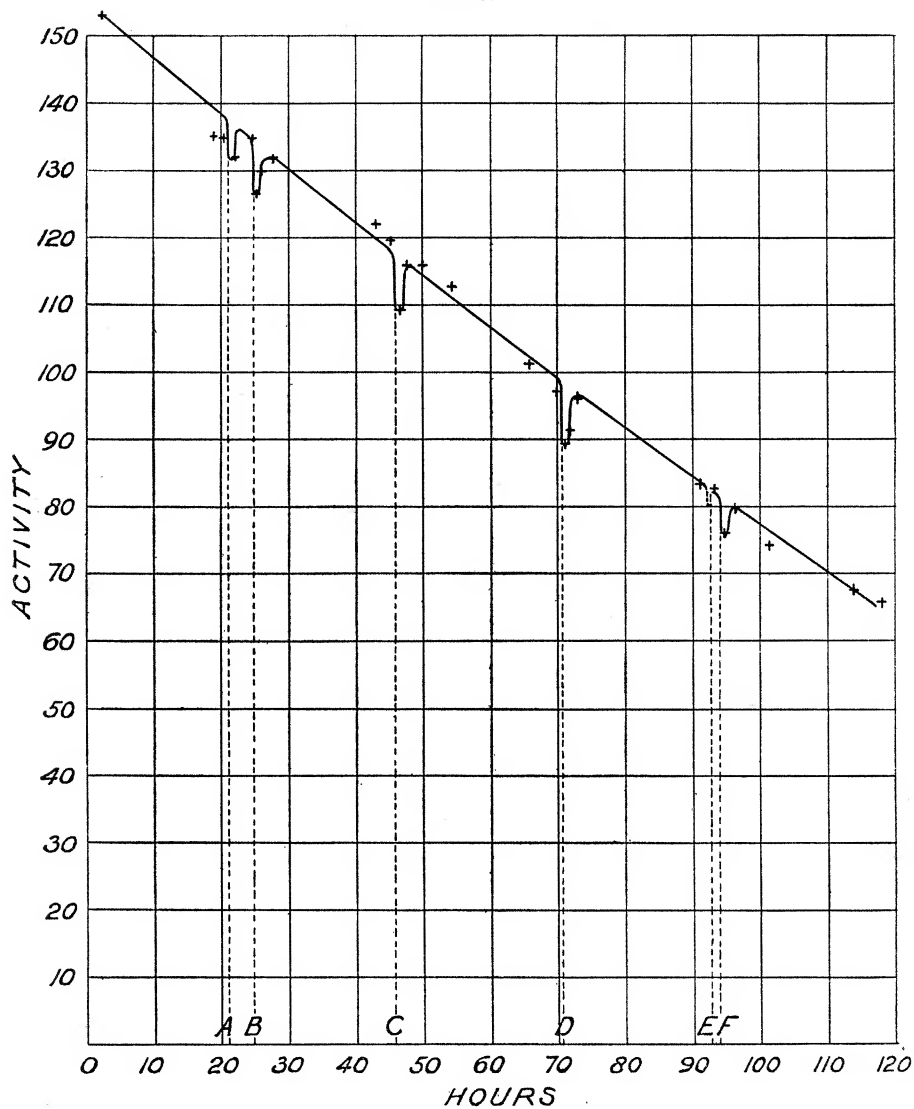
The change in activity increases with rise of temperature, being small at 1000° C. and increasing up to 1200° C. If the results are to be explained on the view expressed by Curie and Danne, the maximum change of activity should occur at 1100° C., and heating to a higher temperature should have less effect. This does not appear to be the case if the estimates of the temperatures in the first series of experiments can be trusted. Accurate measurements above 1200° C. will shortly be undertaken with a view to settling the question.

The observations D, E, F were made after heating the quartz-tube to nearly the same temperature. Heating for 10 minutes produced little, if any, effect, which certainly did not persist for more than a few minutes. Heating for two hours was, however, no more effective than heating for one hour. This is just what would be expected if it is the radium C which is affected.

Table II.

Experiment.	Time of heating, in minutes.	Temperature centigrade.	Activity.		
			Before heating.	After heating.	Percentage fall.
A	60	1000°	138	132	4·35
B	60	1100	134	126·5	5·6
C	60	1220	118	109	7·6
D	60	1185	98	89·5	8·7
E	10	1190	83	80	3·6
F	114	1200	81	76	6·2

FIG. 3.



5. Summary of Results.

(1) The activity of radium emanation in radio-active equilibrium with its products A, B, and C, is changed by heating above 1000°C .

(2) The effect increases with the temperature up to 1200°C ., and possibly beyond this temperature.

(3) The effect increases with the time of heating for about the first hour, but subsequent heating is without effect.

In conclusion, I have to thank Professor Schuster for lending me the radium used in these experiments. To Dr. Hutton I am indebted for the kind way in which he placed his electric furnaces at my disposal, and for his advice as to the best methods of obtaining the temperatures required.

Polarisation in Secondary Röntgen Radiation.

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In a paper on "Polarised Röntgen Radiation,"* the writer gave an account of experiments which demonstrated the partial polarisation of a beam of X-rays proceeding from the antikathode of an X-ray focus-tube, and verified the theory previously given† of the production of secondary X-rays in light substances.‡

In that paper it was shown that the secondary radiation proceeding in a direction perpendicular to that of propagation of the primary radiation from certain substances placed in that primary beam should, according to the theory put forward, be plane polarised. From gases, however, the secondary radiation was not sufficiently intense to produce a tertiary of measurable intensity, and thus the polarisation of the secondary from them was not verifiable. On the other hand, though heavy metals were found to emit secondary radiation of sufficient intensity and ionising power to produce appreciable tertiary effects, in these metals the production of secondary radiation is a more complex phenomenon, and evidence of polarisation of the secondary beam is not to be expected from experiments upon them.

For the secondary radiator a substance had to be chosen which emitted a radiation of considerable intensity, yet differing very little in character from the primary. It had been shown that from such substances the intensity of radiation is proportional merely to the quantity of matter passed through by the primary of given intensity. A substance permitting the passage of the

* 'Phil. Trans.,' A, vol. 204, 1905, pp. 467—479.

† J. J. Thomson, 'Conduction of Electricity through Gases,' p. 268; C. G. Barkla, 'Phil. Mag.,' June, 1903, and May, 1904.

‡ More precisely, substances of low atomic weight.